Information displays[1]

Technological progress has led to the development of artifacts whose functioning depends on hidden parts. Unlike simple machines, such as hammers, whose effect depends completely upon easily visible motion, more complex devices such as clocks, automobiles, aircraft, or computers may only be used effectively with knowledge of many concealed conditions. Accordingly, these complicated devices need subsystems to reveal their hidden status. Those subsystems are information displays.

These displays share the annotation, annunciation, or visualization functions of the common static displays such as road signs, warning placards and maps. But through their interactivity, they also have become critical links for users having only a schematic idea of how modern devices work. The job of these and all information displays is to provide users with correct, appropriate information of adequate recency, frequency and fidelity, and structure sufficient for intuitive, dexterous interaction.

Development of Information Displays

Nature is the first display

The first information display faced by any person is nature itself. In most cases natural phenomena are self-documenting and they may be understood through their physical associations, i.e. a moving hammer can flatten a nail, or a thumb. As computer-based displays have advanced, designers increasingly have utilized operators' experience with natural phenomena, developing displays that can physically resemble the phenomena or data they represent. In fact, the study of common personal physical and social interaction can provide useful design metaphors.

Dimensions of signal display

Human sensory systems are equipped with detectors which respond to specific forms of energy carrying environmental information. These typically include, the eyes, ears, skin and joints, the chemical senses of taste and smell and the vestibular senses of balance and position. Each sensory system is specialized to detect particular ranges and to discriminate minimal changes. Each sensor's dynamic response also is characterized by processing lag and bandwidth restrictions and specific meanings attached to it by instinct, association or convention. Well designed information displays which stimulate these sensors are matched to users sensory sensitivities. Most current information displays, such as bill-boards, computer displays, automobile horns, or telephone ringers, are visual or auditory. But tactile displays are recently becoming common on pagers. Psychophysical research has been conducted to determine the required display features so that information displays can significantly reduce the likelihood of human errors. Some of these characteristics in visual displays are: brightness, color, letter size and shape, spacing of scale marks. Some in auditory and speech displays are: loudness, duration, timbre, and vocabulary.

Early Information displays

Though most early displays were generally visual, auditory information displays also appeared as signal cries, whistles and ultimately speech and music. The earliest visual information displays took the form of rock paintings and evolved into alphabets, number systems and iconographic or representational art. Developing trade and agriculture led to the need to record spatial knowledge, on maps and astrolabes for example, and to methods of recording and displaying time, e.g. calendars and clocks, for which animated visualizations were developed.

Industrial era mechanization

After the industrial revolution, the number of visual information displays in daily use proliferated. Dial-like displays presenting temperature and pressure became necessary for safe operation of trains, automobiles and steam engines. Information display design was particularly stimulated during World War II by the need for operators to fly aircraft during poor visibility (Figure 1) and to interpret radar displays. In the past decade visual computer displays have become the human interface to most new technology. Recently, virtual environment displays have figuratively allowed users to "jump" into a "virtual reality" created within a display itself.

Insert Figure 1 about here

The basic psychological processes involved in the interpretation of the information presented on all displays, however, are similar. Their signaling energy must be detected against noise, discriminated from alternatives, organized into functional units, attended to, and used to organize behavior.

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[1] Ellis, Stephen R. (2000) Information displays in *Encyclopedia of Psychology* , Kaxdin, Alan E. (ed.) American Psychological Association, Washington, D. C.

Psychological processes

Probably the most important psychological phenomena underlying the understanding of information displays is an observer's sense that the visual environment is spatially continuous and temporally seamless. This impression is striking since all observers' visual input arises from discontinuous sequences of eye movements, 3-5 per second. The sense of a continuous visual "reality" is thus a construction of an interpretive process in which information from other senses is combined continuously with vision to determine a coherent interpretation. The task of a display designer is to annotate this process with displayed information.

Detection

The first requirement for assimilation of a displayed signal is that it be detected. Detection was once thought to be determined by absolute threshold energies which have been established for many sense modalities. Some human senses are exquisitely sensitive to environmental signals, e. g., a totally dark-adapted human's visual sensitivity is limited approximately by quantum variations in threshold stimulus intensity.

But more modern analysis based on signal detection theory (SDT) has shown that detection is not only based on a threshold energy but also on observers' relative tolerance of false detections of signals and failure to detect presented signals. SDT analysis allows separation of an observer's detection criterion from the signal's inherent detectability against background noise. Unlike a signal's relatively stable detectability, the observer's detection criterion is influenced by the costs and benefits of correct detections, false detections, missed detections and correctly noted absences of signal. Thus, the criterion for detecting the presence of a roadside information sign could be set so high as to result in many missed detections relative to erroneous detections. In contrast that for detecting a stop sign could be set much lower since the cost of driving through a stop sign could be catastrophic. This difference in behavior for these two types of signs could arise even if the inherent detectability of the signs were equivalent!

Discrimination

Discrimination is intrinsically more complex than detection since it involves the comparison of at least two display signals. The change in physical stimulus intensity, ΔS_t, just necessary to reliably distinguish one stimulus from a reference stimulus of the same type is called a just noticeable difference (JND). For many stimulus modalities the JND is approximately proportional to of the intensity of the reference stimulus S by a constant factor k, $\Delta S/S = k$. This relationship, known as Weber's Law, holds for many sensory dimensions provided the stimulation is restricted to detectors' middle ranges. It represents a kind of built-in control that allows our sensory system to detect small changes in weak signals while maintaining discrimination capability for and avoiding saturation by strong signals. The detectability of differences between adjacent stimuli is also affected by contrast effects in which the apparent strength of a stimulus is enhanced by adjacency of weaker stimuli.

The assumption that JNDs are perceptually equivalent for all reference stimuli allows the construction of a psychophysical scale which exhibits a typical logarithmic compression. This compression may also be descriptively captured by power functions as studied extensively by S. S. Stevens. This psychophysical compression means that display designers must introduce geometrically larger stimulus increments to warning displays as the intensity of the background noise increases. Fixed or linearly increasing intensities will become progressively less noticeable.

Noise interferes with the discrimination of information on displays not only by providing a masking stimulus intensity but also by presenting distracting perceptual structure. This structure can interfere with the detection and or discrimination of signal stimuli, e.g. a continuous auditory tone sharing frequency content with a warning beep can mask it and inhibit detection of other tones having adjacent frequencies. As another example, a surrounding visual stimulus sharing the patterns of contour and shading of a visual information display, such as a road sign, may provide unintended camouflage. Fortunately, the human perceptual system has developed techniques to perceive tones against noise or to break camouflage. These exploit spatio-temporal structure within sensory displays and are examples of the perceptual organization of information.

Perceptual Organization

As in other display types, the content of visual information displays may differ in several dimensions making it stand out as a figure against a background. For some dimensions, such as color and for some differences in textures, this process is an automatic "popping out" of the area of the display from the background. For example, a gray colored "S" immediately stands out against a field of many black "S"s. For an example in which the "popping out" is absent, consider a field of randomly positioned mirrored "S"s surrounded by a field of randomly positioned normal "S"s. In this case the region of mirrored " Ƨ " s emerges only with scrutiny.

Insert Figure 2 about here

Those perceptual contrasts exhibiting automatic "popping out" were thought to be more elemental and to reflect attentional processes operating simultaneously. Those not exhibiting the "popping out" phenomena were thought to reflect sequential processing since detection of the difference they portray seemed to require specific examination of the individual display elements. This contrast is no longer considered as distinctive as it once was since features supporting "popping out" seem to be on a continuum and observers' behavior can now be modeled by either sequential or simultaneous perceptual processes.

Those more elemental stimulus features are clearly useful to enhance the conspicuity of signals on information displays. Stereoscopic disparity is a notable example since, like color, it can serve as a very efficient cue to break visual camouflage. This effect, not distance cueing, may be its most common visual function. Similarly, motion parallax, the differential apparent movement of objects at different distances during head or body movement, can also serve to reveal otherwise hidden structure and can be exploited in displays placing elements at several depth planes.

The automatic structuring of sensory input into larger elements occurs in all sensory dimensions and exhibits regularities that have been captured in propositions called Gestalt Laws. Objects presented incompletely due to occlusion are, for example, "seen" in their entirety with illusory contours in some circumstances appearing to complete their form. Complex assemblies of lines which may be interpreted as "simpler" 3D objects are spontaneously seen in their 3D as opposed to their 2D rendering. Similar processes occur in other senses, e.g. in audition human listeners spontaneously segregate words imbedded in otherwise continuous auditory signals, even when the stimuli representing the word is incomplete.

The intrinsic tendency of viewers to structure incomplete sensory stimuli into larger meaningful units is another aspect of the construction of a seamless flow of experience in the presence of noise and discontinuities. The significance of this process for information displays is that missing or poorly presented information may be "filled in" by the observers' expectations leading to erroneous perceptions.

Attention

Perceptual organization can take place preattentively without specific effort but intentional assimilation of information from displays requires focused attention. This effort may be considered an allocation of information processing resources which filters out some sensory information so that other information may be processed with greater depth and detail. This selection process is necessary because human information processing resources are inadequate to equally process all simultaneous stimuli. Accordingly, information displays are particularly helpful as alerts in situations in which human operators must simultaneously monitor multiple activities, each of which requires complex judgment, for example, air traffic control.

Representational structure and action

In addition to directing attention to events, information displays can help shape operators' interaction with displayed objects by establishing a representational metaphor that can structure interaction. Information displays can, for example, be designed to preserve the spatial frame of reference of required responses, e.g. the spatial layout and labels of controls for burners on a gas range can guide interaction by isomorphically matching the spatial layout of the burners. More complex metaphors, such as the flow of a liquid, can be used to organize displays of continuous processes such as heat transfer in nuclear-electric generators. Groups of related displays also may be usefully juxtaposed so that when they all indicate nominal operating conditions a global feature such as a straight line emerges. Such a feature could arise, for example, from a group of laterally-arranged, thermometer-type engine temperature displays.

Contemporary computer graphics supports innovative, interactive 3D displays. The viewpoint of the perspective air traffic radar map (e.g. Figure 1 right) could be controlled by user head position. Displays of this type mimic nature itself, but such designs can not depend entirely upon their resemblance to reality to insure that their message is received. Precise interpretation of 3D displays, for instance, requires adaptation of the symbology and geometry so that users are not forced to make relatively difficult 3D separation judgments to determine 2D locations. Thus, developers of information displays need to preserve the analytic function of displays so that even with intuitive, naturalistic design metaphors imitating nature, the desired information is detectable, discriminable, organized, and controllable.

Suggested Readings

Sources for Display Standards

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Boff, Kenneth, R., Kaufmann, Lloyd, , and Thomas, James P. (1986) Handbook of perception and human performance, vol. 1-2, New York, Wiley.

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Design of Information Displays

Bertin, J. (1967 / 1983). Semiology of graphics: diagrams, networks, maps . Madison, WI: University of Wisconsin Press.

Tufte, E. R. (1990). Envisioning information. Cheshire, CO, Graphics Press.

Cleveland, W. S. (1994) The elements of graphing data . Rev. ed. Murray Hill, N.J.: AT&T Bell Laboratories.

Figures and Captions

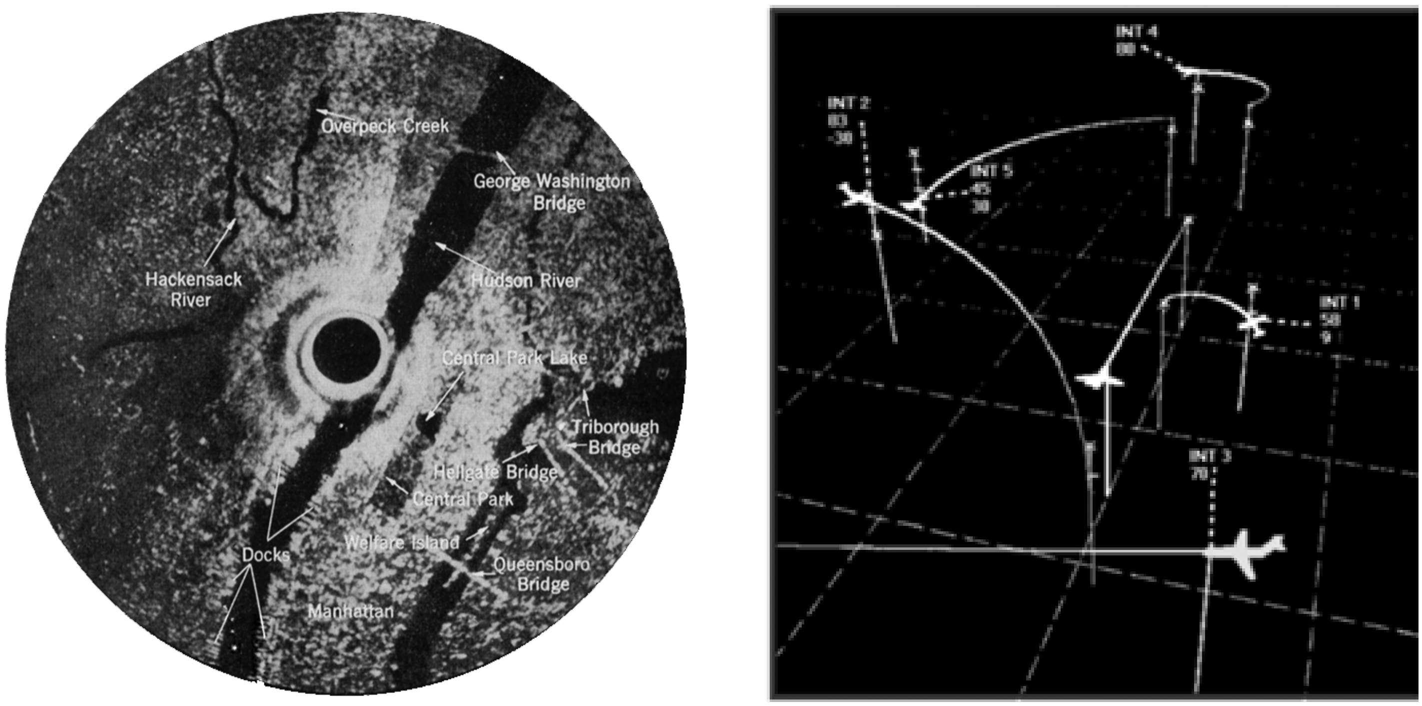

Figure 1. Left: Airborne radar image of New York City made in the late 1940's. Right: an experimental cockpit display of simulated air traffic drawn in 1984 in a more natural perspective format by computer graphics.

(Left image from Radar aids to navigation by John S. Hall, McGraw-Hill, New York 1947 p. 98., Right image courtesey of NASA Ames Research Center, Moffett Field CA)

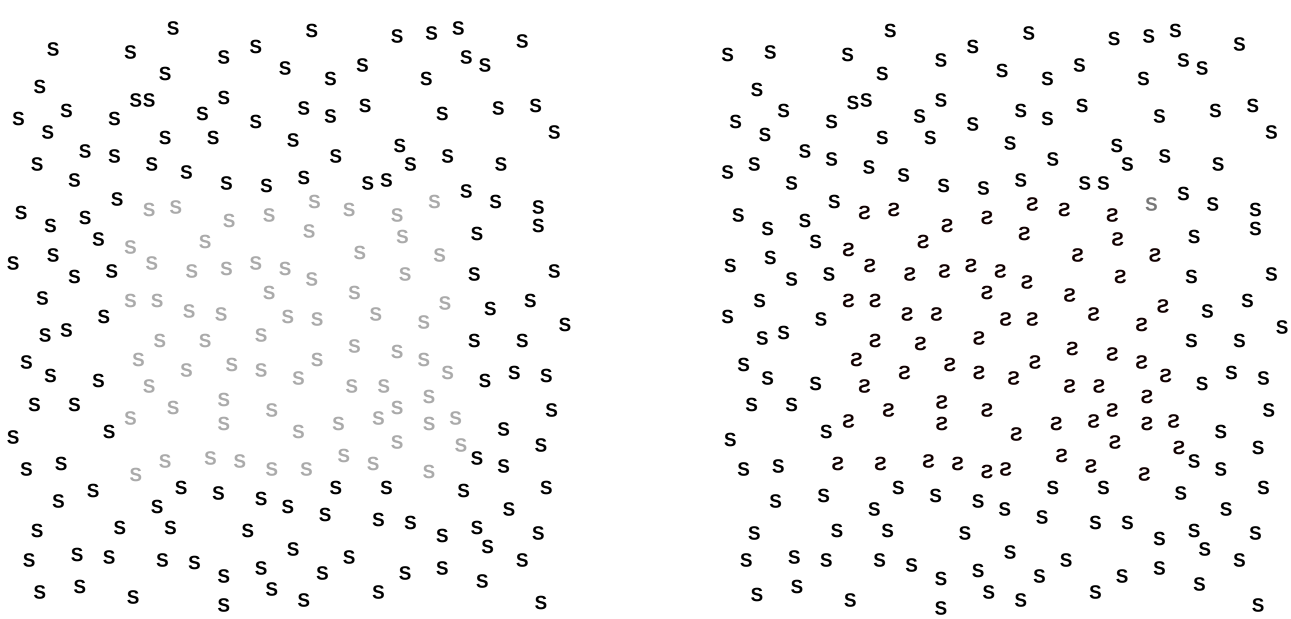

Figure 2. Left panel: Differential shading supports figure ground organization. Right panel: Changing handedness of a texture element does not.